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Energy Efficiency Through Multimedia

It's been some time since you last went window shopping. This weekend, you're replacing several panes broken by next door's Little League baseball player. You figure you'll go to the local hardware store and match a style with the dimensions you've scribbled on the napkin in your pocket; nothing to it. Instead, a sales rep leads you to a computer monitor that proceeds to ask questions about your house, tell you about energy-related window characteristics, and prompt you to try several replacement window configurations, furnishing energy use and cost information for each. You've learned more than you ever imagined about windows with specifications that will lower your electricity bills and help the environment. It was your first multimedia information experience.

Jack Thorpe, Michael Wilde, and Saba Rofchaei demonstrate the new DOE Office of Building Technologies Multimedia Kiosk.

Multimedia

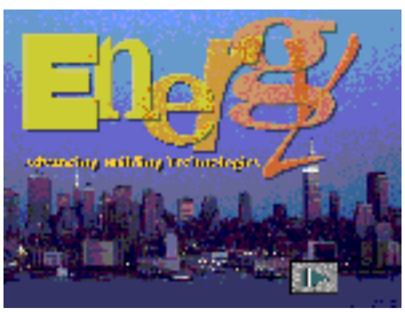
Most people have heard something about this new computer-based technology. Multimedia is the most visible manifestation of a profound communications revolution affecting science, business, and education. It combines computer-based text, graphics, photos, animation, video, and audio; anything that can be digitized. An essential ingredient of multimedia is its interactive experience, a stimulating, user-directed exploration of information.

Quick to pursue this new technology, the Building Technologies Program began conducting multimedia research more than eight years ago. After initially slow progress during the technology's infancy, research blossomed.

Today, five multimedia projects are either complete or in progress. All five have taken shape as either educational kiosks or design tools.

Educational kiosks use multimedia technology to package information in exciting ways, making the learning experience more rewarding. The kiosks employ touch-screen monitors and navigational "buttons" through which text, photos, computer animation, audio, and video are accessed. The philosophy behind these kiosks is that a combination of media types can best illuminate the subject matter. A kiosk's instructional designer can express an idea more clearly, and the user can understand it better when text appears next to a picture or video clip than if the text or photograph stands alone.

The Southern California Edison Kiosk, funded by SCE, was designed to explain the power utility's incentive programs, advise designers concerned with energy efficiency, and provide general information about how energy is used in buildings. The target audience includes the staff of SCE, building owners, and industry professionals (architects, developers, and engineers). The kiosk was developed to transfer information about the utility and efficient technologies to the building industry.



Caption

The Building Technologies Multimedia Kiosk, a project funded by the U.S. Department of Energy, dispenses information about energy use in buildings and the research "know-how" of the national laboratories, including LBL. Several media formats; text, photography, laser-disc video, digitized audio and video, and computer animation; have been incorporated into the kiosk. Developed for the IBM PC, it is perhaps the first true multimedia project undertaken by the Building Technologies Group. The kiosk was designed as a portable unit and is scheduled to visit DOE headquarters in Washington, D.C., as well as regional support offices and building industry events during 1994. In the future, the information in the kiosk will be published and distributed on CD-ROM.

The design tools developed in the Building Technologies Program focus on using multimedia technology to help designers make decisions about real-world energy-efficient designs. Multimedia is particularly useful here because the design process requires architects to consider and manipulate many different types of information. They call on graphics to describe buildings or objects, photographs and video to establish a context for the design, numeric information about building energy performance or cost, and textual information concerning codes and standards specific to the site location. Multimedia's ability to combine these media types makes it ideal for design-tool applications.

PowerDOE is a user-friendly, interactive version of the DOE-2 energy-simulation software with a multimedia interface. It is much simpler to use than standard DOE-2 input routines and includes pull-down menus, component libraries, graphical representation of the building and its performance values, optional links to CAD packages, and the ability to run calculations on generic building types early in the design process. The program structure is designed to allow independent developers to write their own "analysis modules" that can be linked to the PowerDOE software and integrated with the user interface. PowerDOE 1.0, funded by the Electric Power Research Institute and DOE, runs under Windows on the desktop PC and is slated for completion in early 1995.

The Energy Design Advisor (EDA) is a tool that helps architects and builders quickly evaluate different solutions in the schematic design phase by allowing them to change design elements easily and see how their changes affect overall performance. This analysis is performed by the PowerDOE tool, described above. The complexity of PowerDOE is hidden from most users unless they choose to access it. Added multimedia functions allow designers to "walk through" buildings in a case-studies database, listen to interviews of building occupants, see photos of the site for which they're designing, or browse through manufacturers' catalogs to see which lighting fixture looks best. When completed in the spring of 1995, EDA will be available free of charge to building industry professionals. Two modules funded by Pacific Gas &Electric, SCE and DOE, including the case-studies database, are currently under development.

The Residential Fenestration (RESFEN) tool helps users select efficient windows for the home. It was originally developed for use by the National Fenestration Rating Council (NFRC) to determine annual energy ratings (see Seeing Windows Through) and is now being developed for other users in a multimedia kiosk format. Users enter information about their homes, such as location and construction type, through an easy-to-use interface. Then they choose a window element, such as glass or frame type, and the kiosk provides energy use and cost figures for that element as it would behave in the home. RESFEN has been developed as a stand-alone kiosk that could, for example, help customers in a local hardware store with their window choices. In fact, a working version of RESFEN is now assisting homeowners in a Los Gatos, California, window store. RESFEN exists in Macintosh (SuperCard) and IBM PC (ToolBook) formats.

The Building Technologies Program's multimedia project has only begun exploring the potential of multimedia technology. Its current slate of projects calls for a multiyear effort with support from DOE, local power utilities, and other sources. The phenomenal increase in computer capabilities and the simultaneous decrease in cost have assured multimedia a role in the development of design tools and information kiosks at LBL.

Jack Thorpe
Michael Wilde
Building Technologies Program
(510) 486-6847; (510) 486-4089 fax

Accomplishments

The Multimedia Development Lab has created interactive products for industry and government:

- An interactive kiosk in the lobby of DOE headquarters, located in the James Forrestal Building, teaches visitors about the building research activities of the Office of Building Technology
- RESFEN is a multimedia program now installed in some hardware stores that helps consumers compare the energy efficiency of different windows
- The lab designed a multimedia kiosk for Southern California Edison to help educate customers on saving money by cutting their energy bills

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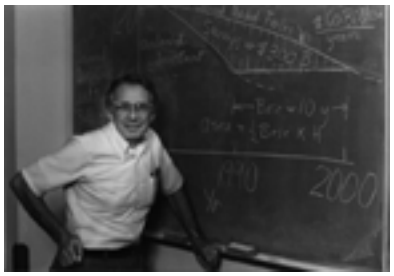
A Viewgraph from the Director



Art Rosenfeld

The Implementation Age: Don't Forget R&D

The energy-efficiency community welcomes the federal government's renewed emphasis on implementing new technologies to save energy, money, and the environment. A product of this new direction is the Climate Change Action Plan, which aims to cap U.S. carbon dioxide emissions at 1990 levels by the year 2000. Building energy efficiency will play a major role in the plan in the form of strategies like:

- Increased government-industry-utility collaboration to produce "market pull" programs
- designed to boost sales of new technologies.
- Emphasis on retrofitting public buildings for energy efficiency, getting government to practice what it preaches.
- Training, information, and demonstrations for consumers and building professionals.
- More state-level initiatives and federal-state cooperation.
- Stronger minimum efficiency standards.
- A new "cool communities" initiative to use light surfaces and trees to mitigate urban heat islands (see Heat Islands) thereby reducing smog and peak power.

But let's not lose sight of R&D, the very activity that made today's new technologies available. Furthermore, stabilizing emissions by the year 2000 is just the beginning of what's needed to cope with the specter of global warming. Maintaining even modest emission reductions beyond the year 2000 means keeping the energy-efficiency pipeline flowing, through continued new development as well as the debugging of existing technology and delivery mechanisms. That expression "technology is here" in this case isn't quite correct.

Let's look at the benefits and costs of LBL's first 17 years of energy-efficiency R&D, then estimate future benefits. Technological developments in which LBL has played a lead or supporting role include electronic ballasts, compact fluorescents, and low-emissivity glazings. At saturation, these three technologies will be saving $17 billion a year, or the equivalent of 38 electric power plants, 140 offshore oil platforms, or 50 million 25-mile-per-gallon cars on the road. How many years of annual benefit can we claim? The R&D probably advanced commercialization by at least five years, giving U.S. industry a five-year advantage over foreign competition.

If the commercial availability of these new technologies was accelerated by just that amount, the original benefit/cost ratio of DOE's R&D investment is about 14,000:1 ($17 billion/year times five years divided by a total DOE investment of $6 million)!

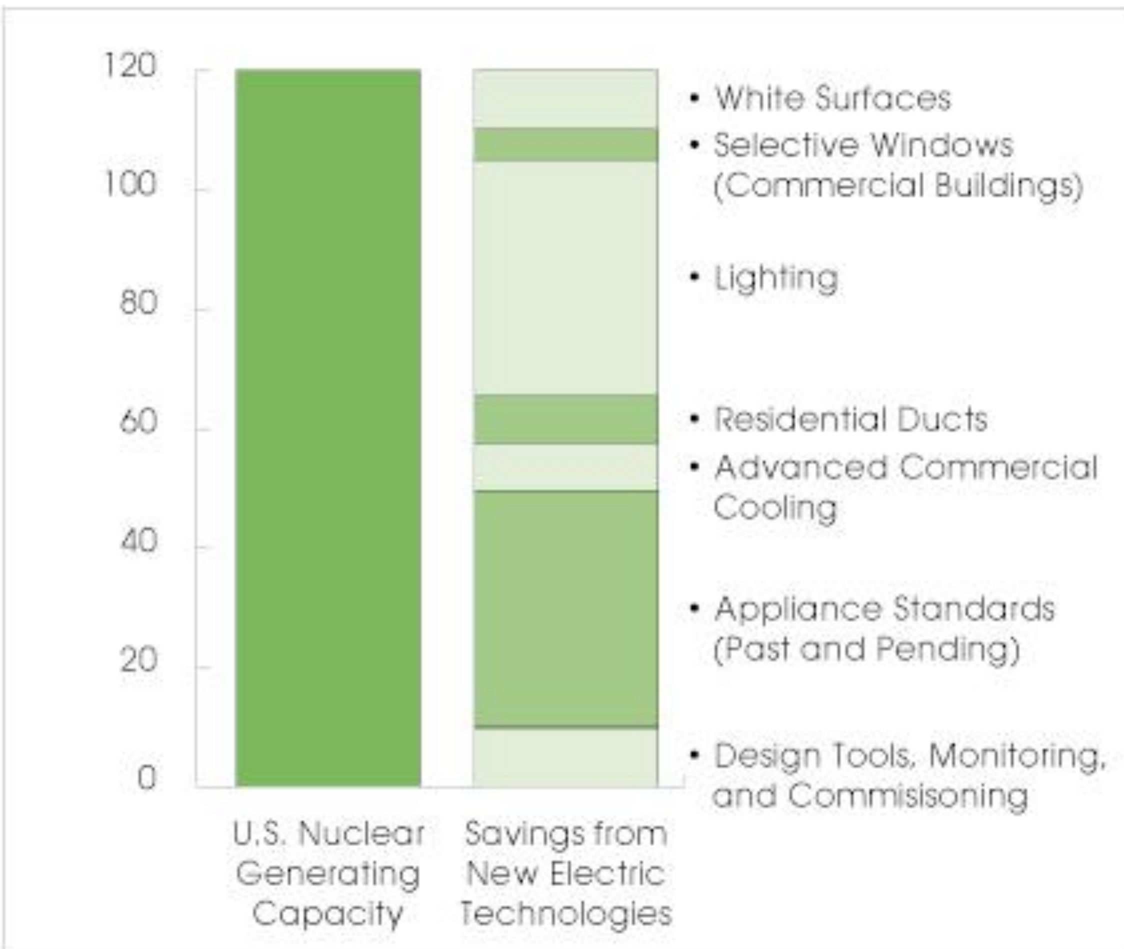
In fact, for our entire research program, including technology development and other activities, each research year has cost the U.S. Department of Energy about $10 million. This cost compares with $17 billion of savings per year over 17 years of R&D, amounting to $1 billion in savings for each year of research- and that's only savings to the present from technology that has yet to saturate the market. This incomplete saturation suggests what we need to do next.

The great challenge in the coming decades will be to link R&D and implementation. Meeting it will require improved analytical methods for tracking savings and product performance, intelligently commissioned energy-efficiency measures to ensure they perform as intended, and brand-new technologies. Some exciting things on the horizon include:

- "Cool" paints and other materials to reduce the heat-island problem.
- Superwindows that ultimately will gain more heat than they lose- even facing north;
- Second generation lighting technology, especially controls.
- Measures to reduce losses from ducts in new and retrofit buildings.
- Radiant cooling for commercial buildings, which substantially reduces the amount of energy required to distribute "coolth." It

also eliminates the need to recirculate air in buildings; this air, we're learning, contains pollutants, bacteria, and viruses.
- Advanced design tools to help architects and engineers make better use of efficiency strategies.
- New energy end-use monitoring strategies and computer tools that help diagnose problem areas.

Together, these new technologies and approaches-along with potential enhancements to appliance standards-stand to save about 120 GW of electrical generating capacity. That's equivalent to about one Climate Change Action Plan in saved carbon dioxide (representing ~110 megatons of carbon) and the energy generated by all U.S. nuclear power plants.



However, none of these technologies are completely market-ready. Notably, most of them received their initial support not from DOE but from gas and electric utilities. The California Institute for Energy Efficiency, funded by the California utilities, has been especially successful in this arena (see CIEE

Conference at Berkeley). It remains to be seen how the utilities and government can support efficient energy technology development more effectively.

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News From the D.C. Office

Lubricating the Market for Energy-Efficient Products: Snake Oil vs. Slick Databases

A handful of tools are essential for those involved in analyzing energy-efficiency policies or designing and implementing programs, no matter what their area of interest or institutional or individual role. My own short list includes:

- Detailed information on the structure of energy end-use and market trends.
- Empirical data that document the real-world performance of technologies and programs.
- Simulation models that use these data to shed light on the future impact of policies and programs.
- Accessible, accurate information on the efficiency, costs, and other characteristics of energy-efficient products.

My colleagues could certainly add to this list, but for now I want to focus on the last item: data on energy-efficient products.

Participants at last January's meeting of the Consortium for Energy Efficiency discussed the need for comprehensive, accurate, up-to-date, and easily accessible data on energy-efficient products. Good product data represent, on the one hand, a requirement common to many utility and government "market-pull" strategies and, on the other, an opportunity for coordinated action by CEE members and others. CEE has formed a working group on product efficiency data. I will be working with this group on behalf of LBL and the U.S. Department of Energy's Office of Building Technologies.

The CEE working group agreed that the data problem has two components: wasted efforts through duplication and inconsistencies, and significant gaps or lack of access to the data. A number of industry and trade associations already compile and publish product data within their limited terrain (some alphabet-soup examples: AHAM, ARI, GAMA, NLPIC, and NFRC). But these follow different formats, are sometimes difficult to use because of arcane systems of model identification, and often are not easily accessible even to practitioners or policy wonks, let alone to the "average consumer."

Existing federal requirements for appliance labeling do little to help even the most motivated consumers identify a best-practice model. For some products-for example, commercial equipment and lighting covered by the Energy Policy Act of 1992-there is no standardized method of measuring energy use or efficiency. Often, utilities and government agencies alike are reluctant to take on the task of cataloging and publishing data on efficient products by brand and model number. They are concerned about legal liability from inaccurate or incomplete data and political liability from information that, even when correct, may defame the less-efficient products. Agencies also hesitate when faced with the significant costs of compiling, updating, and disseminating product data.

On the other hand, at least four states (California, New York, Washington, and Florida) now compile data on energy-efficient products. Federal procurement agencies have begun to publish catalogs and develop on-line data systems for a few energy-efficient products. LBL's Appliance Standards Group is starting to collect product data in selected appliance categories. Groups such as ACEEE, E-Source, and *Home Energy* magazine occasionally publish specialized lists of efficient products.

The proposed DOE Regional Centers for building efficiency, Environmental Protection Agency's voluntary action programs, and other new market-pull and outreach initiatives triggered by EPAct and the Climate Change Action Plan offer new channels for both wholesale and retail dissemination of product information. Finally, "eco-labeling" programs that incorporate energy efficiency, such as Canada's Environmental Choice Program and the privately sponsored PowerSmart and Green Seal programs, need to keep track of the products they certify and label.

Through its new working group, CEE now provides a forum for coordinated planning and action among these potential partners. A first step will be to specify the needs for product data and catalog existing or proposed data sources. The group then hopes to identify options for a sustainable and coordinated national data network that links existing and planned efforts by industry, utilities, government agencies, and other interested parties.

—Jeff Harris

Environmental Energy Technology Division
1250 Maryland Ave. SW, Suite 150
Washington, D.C. 20024

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Carrying the Ball on Radon

Part one of two parts

Radon gas was "discovered" as an important environmental issue in the mid-1980s, when levels 1,000 times the average of about 1.5 picocuries/liter (pCi/l) were found in homes in the eastern United States. Radon is present in all homes, and even in outdoor air, because it is a gaseous decay product of radium naturally present in the soil. Since even an average indoor exposure to radon's own decay products-isotopes of polonium, bismuth, and lead-was estimated to cause a 0.1 to 1% risk of lung cancer, depending on whether one smoked, these high levels sounded an immediate alarm.

By the mid-1980s, scientists had already proven that indoor radon levels 10 to 100 times the average-an unacceptable amount-occurred in homes in various locations throughout the U.S. They also knew why levels could vary so greatly from one home to another and what could be done to lower levels that were deemed excessive. This knowledge had been gained during a broad effort by the research community beginning in the late 1970s and led to a large degree by the LBL radon group. Treating the problem as one of building science, LBL scientists spearheaded efforts to understand the physical processes accounting for radon entry and to analyze systematically the U.S. data from monitored homes.

The Indoor Environment Program's Efforts
These are still major interests of the Indoor Environment Program's Radon Group. Other IEP groups are studying airborne chemicals, emissions from combustion appliances, control techniques, and the energy performance of buildings. The program's basic approach is to investigate the behavior of indoor pollutants and associated air and energy flows. This has led to the recognition that the small pressure differences across the building shell that drive the overall infiltration of outdoor air to the interior could be drawing radon-bearing air from the soil, through the substructure, and into the occupied space.

The radon group's investigation of this process and of measures to reduce radon entry continues. One major effort has involved placing a pair of "small structures," essentially small basements, in the ground at a site in the Santa Cruz mountains and equipping them with an array of sensors for measuring pressure, radon concentration, and temperature in the surrounding soil. The purpose is to investigate, in long- or short-term controlled experiments, the dependence of radon entry rates on these parameters for various artificially imposed pressure differences between the structures' interiors and the outdoor air. In an-other effort, the group has expanded its development of computer models that simulate the transport of air carrying radon from the soil into homes. Increasingly, they use these models to evaluate the effectiveness of proposed control methods, particularly "subslab ventilation" techniques, which alter the pressure field and associated air flows between the soil and the building interior.

Caption

A third research area involves analyzing various types of radon field data gathered across the country, data that provide the basis for both understanding risks to humans from radon exposure and designing effective control strategies. A 1984 analysis yielded a tentative frequency distribution of indoor concentrations in U.S. homes averaging about 1.5 pCi/l and an estimate that about 7% of single-family houses have concentrations above 4 pCi/l, the action guideline set by the Environmental Protection Agency in 1986. This tentative distribution introduced some reality to the debate over radon and was confirmed in the early 1990s by a multimillion-dollar EPA survey.

Critical Evaluations

Since 1986, researchers familiar with the concentrations and behavior of radon, those at LBL among them, have criticized the EPA's representation of the radon issue and its strategy for control. One focus of criticism has been the EPA's use of short-term monitoring data, often taken in basements, to indicate that 20 or 30% of homes exceeded the EPA guideline. In point of fact, only the long-term average exposure is relevant to risk, and primary living space is where most of the exposure occurs. The EPA has also tended to exaggerate risks, most recently exposing itself to criticism for asserting that children in schools were at greater risk from radon exposure than the adults.

A fundamental issue is whether the nation's control strategy ought to reduce radon levels everywhere or, instead or first, mount a concentrated effort to identify the homes with particularly high levels. For example, 50,000 to 100,000 homes are estimated to have annual average concentrations in primary living space of 20 pCi/l or more. This level causes an annual radiation exposure roughly equal to the occupational exposure limit (established for underground uranium miners, the group that provides most of the data for estimating the risk from radon exposure). Twenty years' occupancy of such a house would yield an added risk of lung cancer of about 1%, even among nonsmokers. This level of risk is very high compared with the risks estimated for other kinds of environmental exposures regulated by the EPA.

However, the average level of radon in homes is also estimated to cause risks at the 0.1% level for nonsmokers, larger than other known environmental risks, including radon outdoors. The result is that the EPA's regulatory effort has focused on near-average indoor exposures, engendering a conflict over the orientation of control strategies. The conflict is unlikely to be resolved without more careful evaluation of inherent risks in the indoor environment.

In 1992, I published an article called "A National Strategy for Indoor Radon" in *Issues in Science and Technology* (Fall 1992, pp. 33-40), explaining what had happened since the mid-1980s and proposing an alternative course. The article recommended a commitment to several near-term steps:

- Accurate and effective public information.
- Effective monitoring and control techniques.
- Finding and fixing the high-radon houses.
- A proper protocol for home sales (using an insurance scheme based on pooled funds to pay for long-term measurements) and-where necessary-remedial action.

It also proposed several longer-term initiatives, including:

- Forming a radon advisory committee to assist the EPA in generating and understanding radon.
- data and formulating information for the public.
- Developing a conceptual framework for controlling risks in the indoor environment that would provide the background for making choices on control of ordinary levels of radon.
- Writing building codes aimed at reducing radon levels in new homes, particularly in high-radon areas discovered through programs to identify high-risk areas.

To some extent, the EPA has been trying to remedy the failings of its outreach program (in its public information efforts, for example). However, plenty of evidence suggests that this remedial effort is superficial: it still relies on short-term measurements. Its current proposal of a model building standard is not based on sound science and has not been tested adequately. Finally, the manner in which the agency has been representing data from schools is a repeat of how it exaggerated data from homes. It emphasizes the percentage of schools with one or more school rooms exceeding 4 pCi/l in short-term measurements rather than the fact that levels are generally lower in schools than in homes. In any case, because less time is spent at school, 4 pCi/l contributes very little to a child's annual or lifetime exposure. Much remains to be done to achieve a sensible and effective national radon strategy.

—Anthony Nero

Next issue: developing a methodology for identifying high-radon areas.

Anthony Nero
Indoor Environment Program
(510) 486-6377; (510) 486-6658 fax

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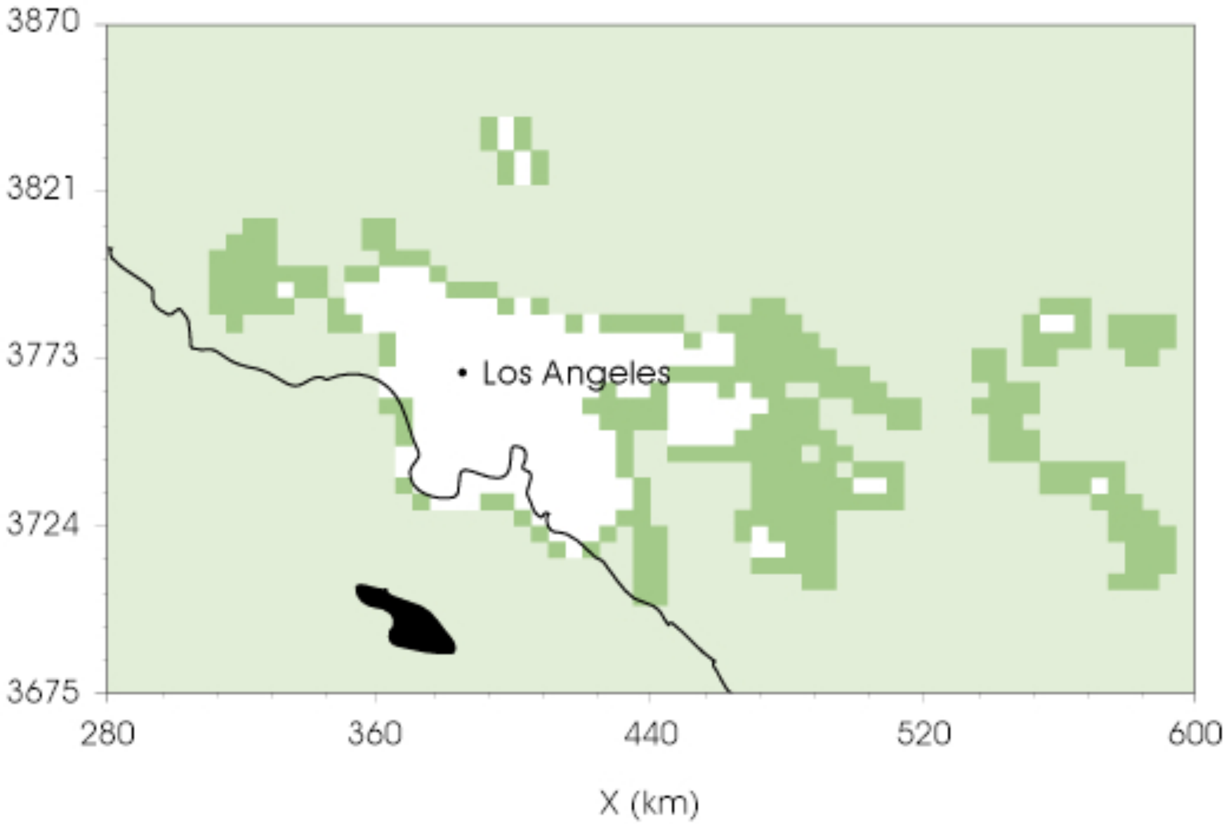
Heat Islands - And How to Cool Them

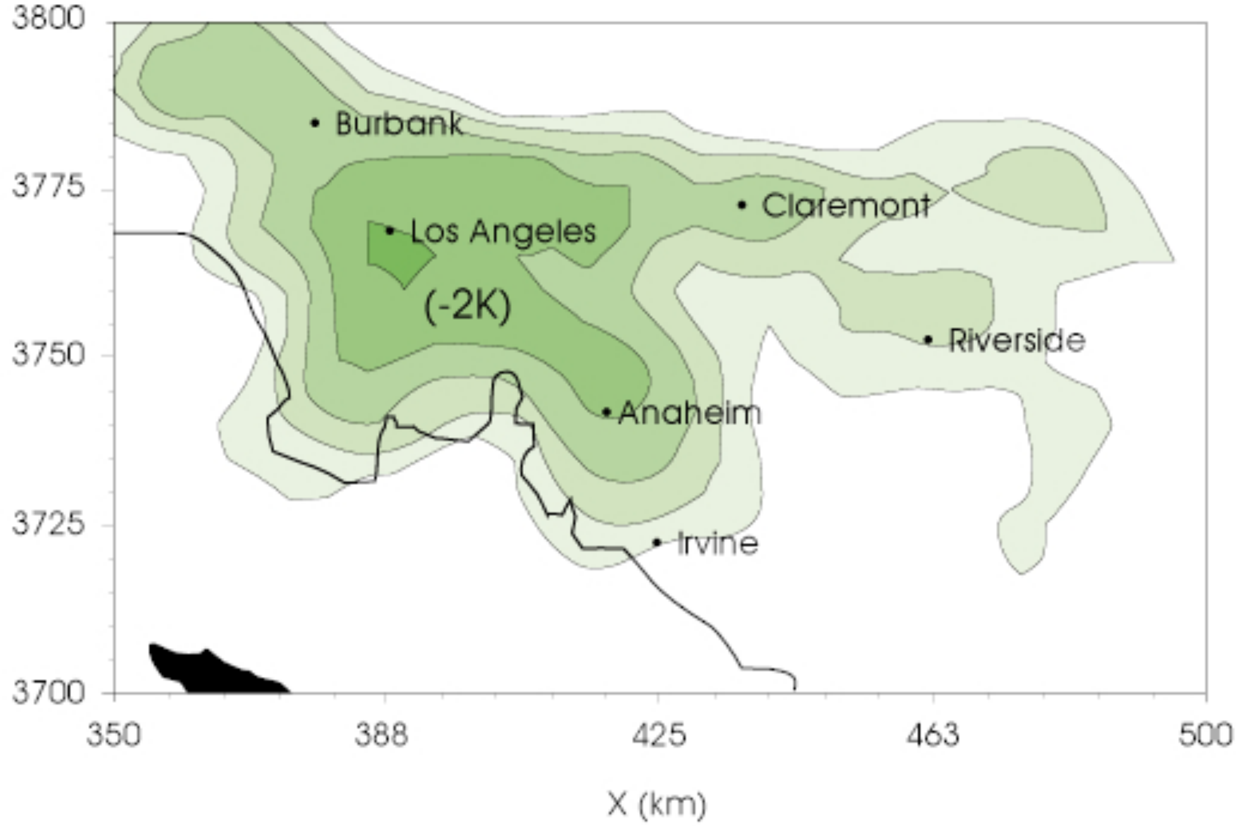


Albedo modification results: Regions within the modeling domain that have been identified for simulated albedo augmentation. Dark green areas are unmodified, light green areas represent modification of less than 0.10, and white is a modification in excess of 0.10. The average albedo increase over the 394 modified cells is 0.16. The second graphic in this document (depicting the central part of the first map) shows the difference between the high-albedo case and the base-case simulation at noon.

The desert oasis is often represented in movies as an island of cool green palms and a running spring or pool amid a sea of sand. The urban oasis is in some ways its opposite, a dark "heat island" whose temperature profile stands out from the cool greenery of the surrounding countryside.

Since 1985, a group of LBL researchers, including Hashem Akbari, Art Rosenfeld, Sarah Bretz, Beth Fishman, Dan Kurn, and Haider Taha, has been

studying urban heat islands and ways to mitigate their high temperature. They have found that on a summer day, the average temperature in a typical American city is about 3 to 5 degrees F hotter than the surrounding area; they also estimate that air conditioning to cool cities from this effect accounts for 5 to 10% of urban peak electric demand. In Los Angeles alone, the additional electricity costs more than $100 million per year, not counting the costs of the added smog concentration caused by this
heat.



Islands in the Sun

The elevated temperatures of urban heat islands are increasing with population and new building growth. Since 1940, temperatures of many cities have climbed steadily by 0.25 to 1 degree F per decade. A hot summer afternoon can raise peak cooling demands throughout the U.S. by about 10 GW, which costs several billion dollars each year. Los Angeles has experienced one of the largest observed rises: each 1 degree F rise there increases peak cooling demand by 1.5%.

Heat islands compromise air quality through two mechanisms. First, power plants that generate the additional electricity to meet the load produce pollution.

Second, higher air temperature enhances the formation of smog-in Los Angeles, the probability increases 2 to 4% per degree F. When the city is below 70 degrees F, smog episodes are rare. Smog appears more than 50% of the time when the temperature reaches 90 degrees F. Reducing the daily high temperature by 5 degrees F in Los Angeles could eliminate one-third of its smog episodes.

The Comfort of Shady Trees and Lightened Surfaces

Inexpensive ways of mitigating heat-island effects are as old as human civilization: planting shade trees and changing the color of surfaces so that they reflect more incoming solar radiation, for example, by painting them or covering them with lighter materials. The high "albedo" of a light-colored surface is good at reflecting the sun's energy. Shade trees reduce heat gain by directly shading buildings as well as through evapotranspiration. Results indicate that shade trees can reduce cooling energy use in buildings by about 10% of the capital cost of avoided power plants and air conditioning equipment. Light-colored surfaces can cool even more effectively with more immediate results than shade trees, which take time to grow. The cost of saved energy is less than 1¢/kWh and 2¢/kg of carbon respectively. Assuming an average of 5¢/kWh for electricity, the net cost is 4¢/kWh. The approximate net cost of avoided CO_2 is about -$200/ton of carbon.

To simulate the effects of lightening and greening a city, the LBL scientists used a three-dimensional meteorological model of the Los Angeles Basin consisting of 2600 cells, each 25 km2. They identified 394 of the 2,600 cells as "developed areas" where lightening agents could increase the albedo of the cells' impermeable surfaces. When the albedo is increased by about 0.16, the average difference between the current and lightened Los Angeles at 3 p.m. is 4 degrees F.

Looking for Energy Savings

Seeking to quantify the energy saved from mitigation techniques, Center researchers gathered data during the summers of 1991 and 1992 at residences and school bungalows in Sacramento, California. In 1992, the team placed shade trees at one house for four weeks and measured the home's energy use. After moving the shade trees to the other site, they made the same measurements. A comparison of the homes suggests that the trees saved 30% of cooling energy use in the unshaded building. By changing the albedo of one house's roof from a dark 0.16 to a very light 0.78, the team measured a seasonal air-conditioning savings of about 40% (330 kWh/yr). This work is giving the Sacramento Municipal Utility District the background data for establishing a demand-side management program to save air-conditioning energy. Already, there is sufficient evidence to claim that utility-sponsored DSM programs could save perhaps $100 million per year in energy costs through these simple, inexpensive mitigation methods.

—Allan Chen

Hashem Akbari
Heat Island Project
Energy Analysis Program
(510) 486-4287; (510) 486-6996 fax

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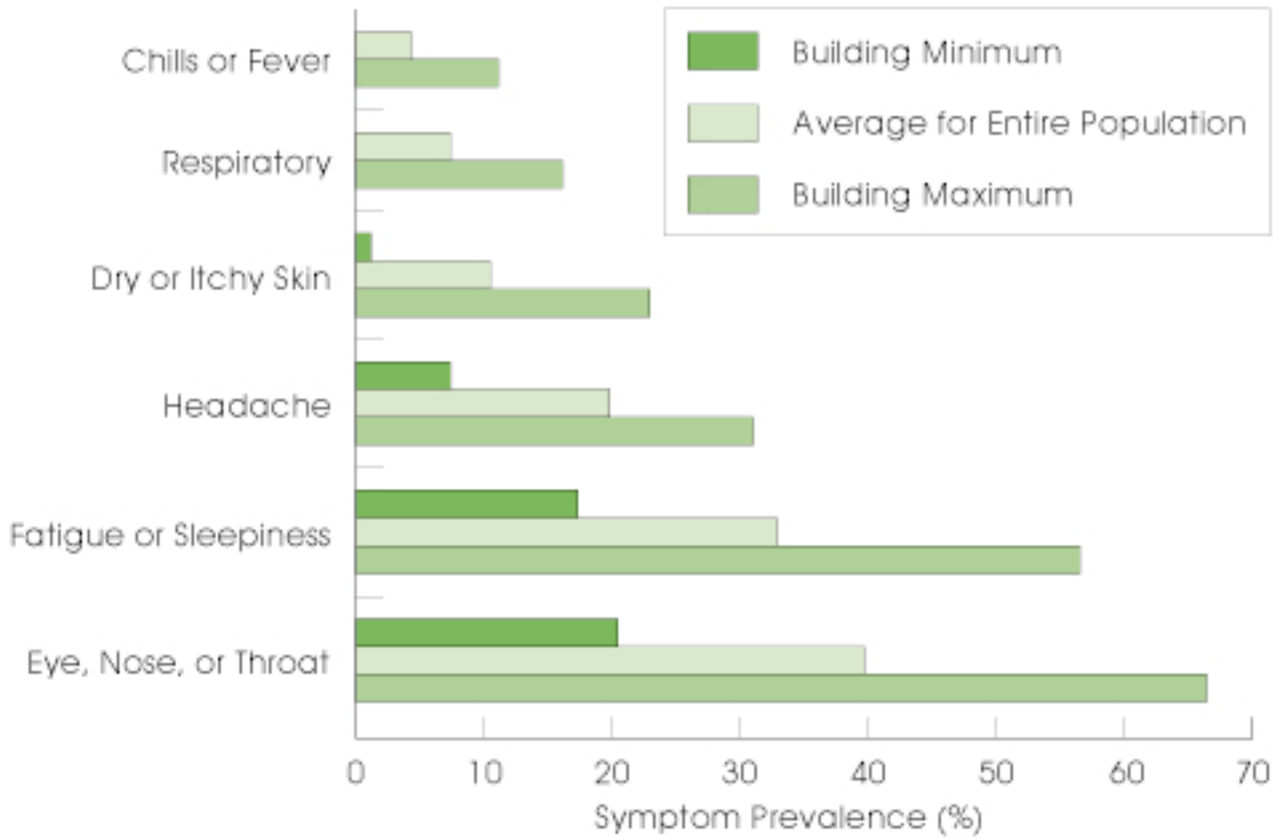
The California Healthy Buildings Study

Buildings can cause health problems - that relationship is well-known. When asked to fill out questionnaires, occupants of office buildings often report that symptoms such as eye and nose irritation, headache, fatigue, and itchy skin are more frequent or severe when they are inside rather than outside their offices. In "sick" buildings, the frequency of these symptoms becomes unusually high. Typically, health officials deal reactively with complaints in office buildings by investigating only the sick building. They interview employees, measure indoor pollutant concentrations, and inspect ventilation systems. However, in many buildings, these measures fail to identify the causes of health complaints.

During the past five years, researchers have started to use cross-sectional surveys of multiple office buildings to identify factors that are statistically associated with health symptoms. This new methodology is yielding valuable information on the causes of these symptoms. The California Healthy Building Study (CHBS) is one of these recent cross-sectional surveys. It is the first survey of this type performed in the U.S. and is a project of the Center's Indoor Environment Program. The researchers are myself, Al Hodgson, Joan Daisey, David Faulkner, and Matty Nematollahi - all with the Indoor Environment Program; Mark Mendell, National Institute for Occupational Safety and Health; and Janet Macher, California Department of Health Services. During the study's initial phases, the researchers gathered background data on health symptom prevalences and indoor air quality in typical ("non-sick") buildings and tested several hypotheses about the associations between the symptoms and features of the buildings, their indoor environments, and jobs performed. The study's long-term goal is to understand how to create "healthy" office buildings whose occupants have fewer work-related symptoms and higher productivity.

Twelve San Francisco-area office buildings were selected without regard for occupant complaints. To better correlate symptoms with method of ventilation, we divided the buildings into three groups: naturally ventilated, mechanically ventilated with operable windows and no air conditioning, and mechanically ventilated with air conditioning and sealed windows. Questionnaires were completed by 880 occupants, who reported their health symptoms and provided demographic and job data. Indoor and outdoor concentrations of CO_2, CO, volatile organic compounds (VOCs), fungi, and bacteria were measured along with indoor temperatures and humidities.



Average symptom prevalences for the entire study population plus the minimum and maximum prevalences in individual buildings. For this figure, a work-related symptom is defined as a symptom that occurred often or always during the previous year and improved when the occupant was away from the building.

Building-related symptoms were defined as those that occurred often or always and that improved when the occupant was away from the building. In the entire study population, for three symptom groups, the symptom prevalence exceeded 19%, suggesting a widespread and significant health problem that requires further study. In all symptom groups, the prevalences varied widely from one building to the next, indicating that some building-related factors have a large impact on occupant health.

The next step was to look for correlations between symptom prevalences and the characteristics of the individual, job, workspace, building, and indoor environment. A few results are worth singling out. For example, buildings that used mechanical ventilation without air conditioning and those using mechanical ventilation with air conditioning had a higher prevalence of all symptoms except headaches compared to buildings with natural ventilation. The association between air conditioning and higher frequency of symptoms is consistent with the results of European surveys. The CHBS is the first study to include a group of buildings with mechanical supply and exhaust ventilation but operable windows and no air conditioning. Elevated levels of symptoms in these buildings are surprising since the building type is not commonly associated with health complaints. One possible explanation is that mechanical ventilation systems are themselves sources of pollutants such as bioaerosols, fibers, and VOCs.

Job-related or workspace factors also correlated with increased prevalences of one or more symptom groups. For example, our finding that the use of carbonless copy paper is associated with increased symptoms agrees with the findings of a Danish study. Organic chemicals in this type of paper may be the cause, and inhalation of vaporized compounds or physical contact with the paper may be the exposure route.

European surveys and the CHBS also agree that increased symptoms and carpets are associated. Carpets could be a source of increased symptoms because they release VOCs or fibers or because microbiological material such as fungi and dust mites find them perfect habitats. In the CHBS, release of VOCs from carpets was probably not the cause of symptoms because the carpets were generally old.

So far, no associations between symptoms and environmental parameters measured in the study have been identified. Most other surveys have also failed to verify a connection between symptoms and indoor air pollutants, but several indicate that the frequency of symptoms increases with temperature. Connections between pollutants and symptoms would not be identified if the study measured the wrong pollutants or if the measurements took place at the wrong times and locations to represent the occupants' exposures adequately. Follow-up studies are underway in the same buildings to investigate the environmental causes of the symptoms. Eventually, the study team will conduct experimental interventions such as increases in ventilation rates or improved office-cleaning practices to evaluate ways of improving the health of office workers.

—William Fisk

William Fisk
Indoor Environment Program
(510) 486-5910; (510) 486-4089 fax

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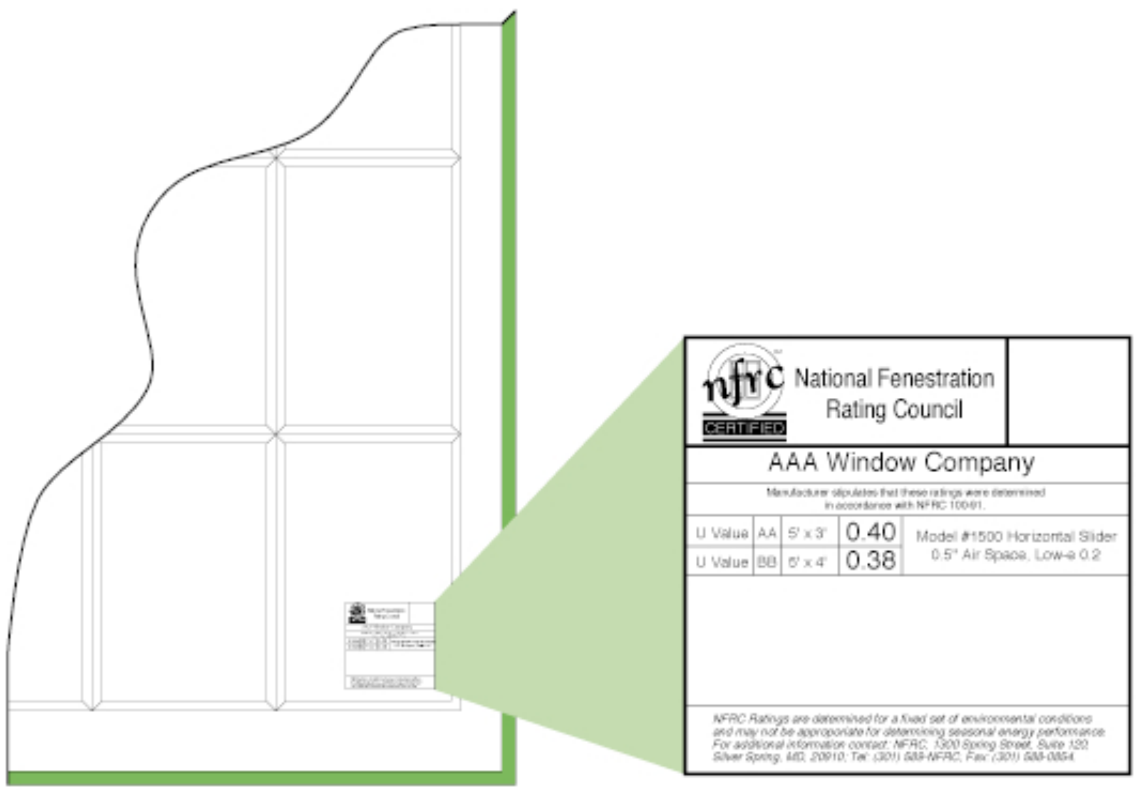
Seeing Windows Through

A profusion of gases, glazings, and gap sizes are among the factors that confound efforts to measure the energy performance of a window or skylight.

The increasing variety of efficiency-enhancing options for windows and their frames poses a formidable challenge to builders, utilities, code officials, and consumers. Fortunately, a new system for accurately rating and labeling these products promises to help demystify them and to foster nationwide improvements in energy efficiency.

NFRC is Born



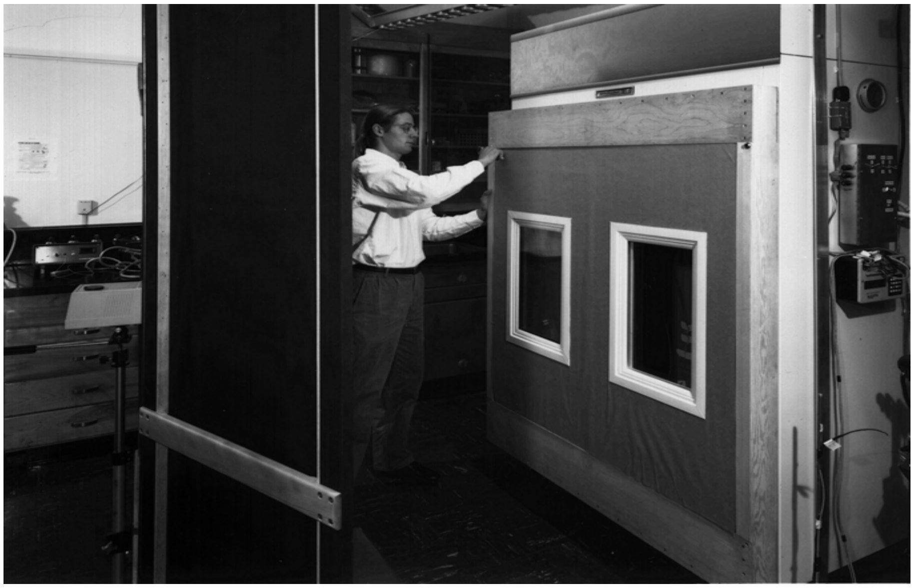
Window trade groups have historically organized around specific materials or components (such as glass or frames), and energy has rarely been their focal point. This changed in 1989 with the formation of the National Fenestration Rating Council. One impetus behind the industry's collaboration with builders, utilities and regulators in establishing the NFRC was the emergence of disparate, mandatory state energy certification and labeling standards for windows. The specter of a national patchwork of nonuniform requirements prompted the industry trade groups to help form the NFRC and to help devise a single national system.

Environmental labeling is especially useful when an important attribute is not visible to the naked eye. These two cans of tuna appear identical, but for one it is certified that no dolphins died in the nets when the tuna were caught. Labels can also tell consumers how two windows that appear identical have very different energy performance.

The Energy Policy Act of 1992 charged NFRC with developing a national labeling and rating program. The Department of Energy and the Federal Trade Commission are empowered to step in and create standards in the absence of industry action. NFRC has already made progress: California, Washington, and Oregon now require windows to be rated and labeled using the NFRC method. Building codes in Idaho, Alaska, and Minnesota have adopted NFRC values, and a dozen other states are considering them or are in the final stages of adoption.

LBL's Windows and Daylighting Group played a large role in helping NFRC's technical committee establish credible methods for determining window properties and creating a low-cost rating procedure. The University of Massachusetts, the Florida Solar Energy Center, and Canada's Energy Mines and Resources also contributed to the technical work.

One LBL contribution to the NFRC process is a software package called WINDOW 4.1, the computational engine behind the NFRC labels. Based on the target window's physical properties, WINDOW 4.1 calculates the total U-value, solar heat gain coefficient, shading coefficient, and visible transmittance, accounting for complex heat-flow interactions. Correcting for factors such as heat loss through frames can, for example, reclassify a super-efficient R-8 glazing (U=0.125) in a poor frame to a whole window value of less than R-4 (U=0.25). The program models specific window types, such as picture, casement, or horizontal slider. Future versions will also model doors and skylights. In addition to being used for rating and labeling, WINDOW 4.1 is a powerful tool for designing prototypical windows from an electronic inventory of glasses, gases, gap widths, coatings, and frame materials.



The WINDOW 4.1 program (version 3.0 shown below) enables a window manufacturer to substitute expensive laboratory tests of thermal performance with computer simulations. A single window test can cost more than $1,000.

A Powerful Cost-Saving Tool

A clear benefit of the NFRC approach is that rating a window's optical and energy characteristics using a computer program is less expensive for manufacturers than laboratory testing. This makes it easier to perform "tests" on a diverse product line and eliminate uncertainties introduced by both errors or "noise" in test procedures and differences from one test lab to another. These complications previously prevented the reliable comparison of one window product to another. NFRC will conduct annual quality-control inspections of institutions that test windows or develop energy ratings.

The next research challenge is to extend labels from showing simple properties to include estimated energy and economic savings. This work will use LBL's DOE-2 program to differentiate among operating conditions that vary regionally, such as climate and energy costs.

The DOE sees NFRC's success as an important breakthrough, and the NFRC experience is now spawning other nonfederal labeling initiatives. Notably, the Home Energy Rating Systems council and the Council on Office Products Energy Efficiency are contemplating similar strategies.

A Window on the World

International groups are coming to LBL to learn how to create window rating systems for their own countries modeled after the NFRC's. One recent example is Valery Tishenko, head of Building Standards at the Russian Construction Ministry (Gosstroy), who wrote DOE expressing interest in improving his country's certification of construction technologies, particularly windows. He asked for help in transferring the NFRC rating procedures and computer programs to Russia.

As the first step in this exchange, three visitors from Russia spent several weeks in February working with Dariush Arasteh, Charlie Huizenga, and other members of the Windows and Daylighting Group to translate LBL's WINDOW 4.1 computer program into Russian. WINDOW 4.1 is the basis for the U.S. window energy ratings system under development by the NFRC.

Alexander Spiridonov, the project leader, and programmers Vladimir Chernorutsky and Michael Vilinsky are from the Sol Company and the Gosstroy Institute. Their work is expected to form the basis of a window rating system for Russia. The visit was funded by the DOE's Office of Building Technologies. Meanwhile, LBL staff, acting as NFRC representatives, trained the Russian programmers as Certified Window Rating Simulators. NFRC plans to complete certification of the window test facilities at Gosstroy's Building Physics Research Institute later this spring.

In February, a meeting of the International Energy Agency at LBL examined window energy-efficiency and rating systems. Representatives of several European countries and Australia looked into adopting parts of WINDOW 4.1 and the NFRC process.

—Evan Mills

Dariush Arasteh
Windows and Daylighting Group
and
Chris Mathis
National Fenestration Rating Council
1300 Spring Street, Suite 120

Silver Spring, MD 20910
(301) 589-NFRC; (301) 588-0854 fax

WINDOW 4.1 is available from NFRC or Bostik Construction Products: (800) 523-6530.

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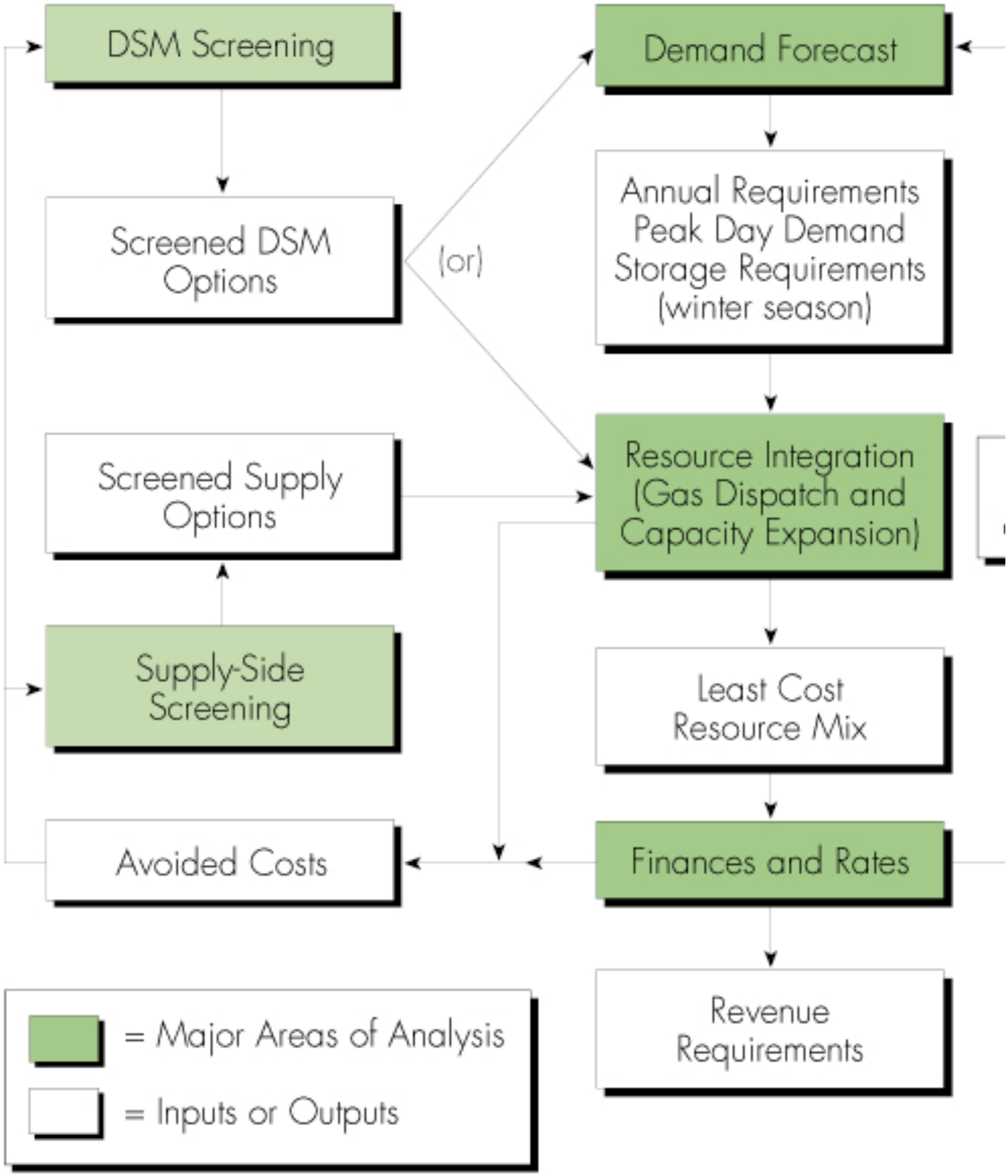
Bringing Better Planning and Energy Efficiency to Gas Utilities

Scientists in the Utility Planning and Policy Group of the Energy Analysis Program recently completed a document designed to introduce gas utilities and their regulators to the benefits of integrated resource planning. IRP is a process used by utilities and public utility commissions (PUCs) to assess a comprehensive set of supply- and demand-side resource options when meeting customers' long-term energy service needs. The document, known as the *Primer on Gas Integrated Resource Planning*,is being published by the National Association of Regulatory Utility Commissioners (NARUC) under a grant from the U.S. Department of Energy.

Interest in gas IRP has increased in recent years for a number of reasons. One is the industry's ongoing restructuring which is being accelerated by recent policy changes at the Federal Energy Regulatory Commission. FERC Order 636 requires gas utilities to become active managers of their gas portfolios. Also, widespread adoption of electric IRP processes has made state regulators aware of the potential benefits of gas IRP. Finally, the Energy Policy Act of 1992 (EPAct) now requires states to consider IRP a regulatory process. Despite the increased interest in gas IRP, until now there has not been a single comprehensive report on the topic. The *Primer* fills the information gap by providing an overview of many regulatory and technical issues raised by gas IRP.

Gas IRP is a controversial topic because it is not clear that IRP, largely developed for electric utilities, directly applies to the natural gas industry, which is less vertically integrated and is subject to greater competition in certain end-use markets. According to LBL principal investigator Charles Goldman, "It is probably not a good idea to conduct IRP for gas utilities in the same manner as the electric utilities do. Compared to the electric industry, the gas industry is not as vertically integrated, does not make incremental investments in large chunks, and does not face the same environmental constraints. Further, the amount of untapped end-use energy efficiency potential appears less. As a result, it may make more sense for PUCs to adapt

IRP regulations to conditions facing the gas industry and, for utilities, to include IRP objectives in ongoing strategic planning processes."



The *Primer*presents the potential benefits and drawbacks of IRP as a regulatory process as well as approaches that states may take to reap IRP's benefits. Several areas of analysis must be coordinated in an IRP process regardless of the regulatory structure in which a gas utility operates: demand forecasting, demand-side and supply-side screening, the integration of supply- and demand-side resource options, and financial and rate planning. A simplified representation of the analysis framework and the relationships between various areas is shown in the figure. In addition to providing an overview of the major areas of analysis in gas IRP, the *Primer*focuses on specific technical areas including:

- Analytic methods and models used to conduct an IRP process.
- Gas utility supply and capacity planning in a "post-636" world.
- Methods for estimating avoided gas costs.
- Methods for estimating the net benefits of utility-sponsored demand-side management (DSM) programs.
- Utility DSM resource assessment and program design.
- Utility fuel substitution programs.
- Ratemaking methods that address the utility financial impacts of DSM programs.

The *Primer* does not resolve major policy issues associated with gas IRP. Instead, it provides a comprehensive discussion of many of the major policy issues and highlights promising planning methods and other analytic tools that gas utilities and regulators are beginning to use in IRP processes. According to Nevada Public Service Commissioner Jo Ann Kelly, who coordinated the NARUC Gas Committee's review of the *Primer*, its development process "was unprecedented because of the amount of input that was received from the gas industry and the NARUC Conservation and Gas committees. As a result, the document is very balanced and will be of great value to many PUCs, especially in light of the requirements in EPAct."

—G. Alan Comnes

Charles Goldman
(510) 486-4637
or G. Alan Comnes
(510) 486-4647

Utility Planning and Policy Group
Energy Analysis Program

To request a copy of the *Primer,*contact Judi Ford at NARUC: (202) 898-2203.

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Center Research Facilities:

Infrared Thermography Laboratory

The human eye can't see heat directly or gauge temperatures, so it needs the help of instrumentation. At the Center for Building Science, researchers Dariush Arasteh, Fred Beck, Brent Griffith, P.J. Donohoe, and Radin Jasek of the Building Technologies Program have developed an infrared thermography laboratory to measure the temperatures on flat surfaces, such as windows and door panels, using an IR scanner. IR thermography provides a quick, accurate measurement of how well a test sample insulates. It's an ideal tool for developing better-insulating windows and panels.

Superinsulating window developers have shifted their attention to the edges and frames of these windows because these areas are now the biggest dissipaters of heat in the window system. According to Griffith, "IR thermography offers a fast, quantitative way of identifying the best frame and edge designs to optimize a window's performance."

The technique is also used to validate finite-element computer models of the components' thermal performance. Center researchers have also studied the use of IR thermography to develop standard tests of windows' ability to resist condensation, an important feature for someone thinking about buying superinsulating windows.

Brent Griffith, left, and Radim Jasek prepare a sample window for testing in the infrared thermography facility. Paul Donohoe, far right, adjusts the infrared camera. The structure attached to the bellows is the newly built room temperature chamber that maintains environmental conditions as constant as those in the refrigerated chamber to its left.

The thermography lab's facilities consist of a refrigerated and a room-temperature chamber, a sample mounting frame that fits between the two chambers, and a high-resolution IR scanning radiometer. This instrument plugs into a PC that stores and processes the images. Scanning at roughly the same rate as a television (20 to 50 frames/second), the radiometer measures the relative temperatures of the sample's surface to within 0.1 degree C. Since the system doesn't measure absolute temperatures as accurately, users take several images of the sample and the PC's post-processing software creates a composite, higher-resolution image. A new addition to the lab is an extended area reference emitter, a four-inch- (10-centimeter-) square sample that emits a known flux of IR radiation. Calibrating test samples against this reference offers more accurate absolute temperature maps.

The freezing chamber maintains steady temperatures between -40 and 10 degrees C. "In 1993," says Griffith, "the room-temperature chamber was upgraded so that its airflow and temperature regime could be controlled and repeated just as accurately as the refrigerated side is." With a standard sample size of about four square feet (0.4 square meters), the scanner can zoom from a view of the whole sample to a close-up of interesting areas as small as an eight-inch (20-centimeter) square. The temperature scans can be color-coded or converted to grayscale. The post-processing software can assign any desired color to contour zones, convert raw data into histograms, measure temperature gradients along the surface, and dress up the images for presentation.

Arasteh and his colleagues use the IR thermography facility primarily for analyzing the thermal performance of windows and insulating gas-filled panels (see *CBS News,* Winter 1993 page 9) Among their current work is a project aimed at understanding the two-dimensional thermal effects of refrigerator/freezer shell design. They have also analyzed lighting fixtures to detect overheating (see *CBS News,* Winter 1993 page 4) and selective glazings for automobile glass. The IR thermography lab is available to researchers outside LBL to solve scientific problems consistent with the facility's purpose. It is also available without charge to manufacturers developing or proving major new products and design approaches; results measured in the lab must be for internal use only.

—Allan Chen

Brent Griffith
Building Technologies Program
(510) 486-5827; (510) 486-4089 fax

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Visitors Far and Wide

California Assemblyman Tom Bates describes his proposal for a new hybrid vehicles industry to LBL staff.

California Assemblyman Tom Bates met with LBL staff recently to talk about the future of California's economy and his efforts to develop a new industry-building hybrid electric vehicles-at the sites of San Francisco Bay area military bases slated for closure. Participants at the January 28 meeting discussed enthusiastically the job-creation and environmental promises of a hybrid-vehicle industry. They pledged to work with a unique government/private-sector collaboration investigating the technological and economic inputs required to get such an industry started. Assemblyman Bates is a member of the

Bay Area's Defense Conversion Task Force and several Assembly committees, including Natural Resources, and is the California Assembly's liaison to the Clinton administration.

Hosted by the Energy Analysis Program and its director, Mark Levine, Project 3 Working Group A of the World Energy Council (WEC) met at LBL in mid-January. WEC is an international organization whose objectives include analyzing energy policy and promoting the peaceful uses of energy. Working Group A identifies ways of using high technology to improve energy efficiency. Representing seven countries- Canada, France, Italy, Japan, Korea, the U.S, and Sweden-the group will present its report at the Triennial Congress of the WEC in Japan next year. Participants at the January meeting finalized the selection of case studies of advanced technologies that can successfully and cost-effectively spur energy efficiency for the report. They also discussed the use of computer information systems in energy efficiency.

Another recent visitor to the Center was John Hoffman, Director of the U.S. Environmental Protection Agency's Global Change Division. Hoffman described the EPA's plans to expand the successful model provided by its Green Lights Program to embrace more energy end-uses in commercial and residential buildings. Possible LBL collaboration with the EPA includes developing advanced CFL fixtures and other aspects of residential lighting; demonstrating and validating advanced technologies such as thermal distribution via radiant cooling and more efficient ducts; improving design tools and decision-support software; developing efficiency rating systems (such as for residential windows); and integrating indoor air quality with the overall concept of "green buildings." Hoffman also identified building commissioning and improved operating procedures as important strategies. New LBL work with geographic information systems will be useful in identifying energy savings opportunities and relative cost-effectiveness at regional and state levels.

Stephen Selkowitz, head of the Building Technologies Program, was a Visiting Fellow at the Center for Advanced Engineering (CAE) at the University of Canterbury, in Christchurch, New Zealand, from February 21 to March 3. He was one of five fellows reviewing and discussing a series of reports on CAE's Energy Efficiency Project for the government of New Zealand. Selkowitz spent the first four days in the Energy Efficiency Project workshop in Wellington. He then described the Center's building energy-efficiency projects and other work at seminars titled "International Perspectives on Energy Efficiency," held in Wellington, Christchurch and Auckland.

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Awards and Citations

Art Rosenfeld, director of the Center for Building Science, has received the Department of Energy's 1993 Sadi Carnot Award for lifetime achievement in the field of energy conservation and renewable energy.

During a 20-year career in the energy-efficiency field, he has contributed to both major analytical advances in energy analysis and practical programs designed to improve efficiency. He also helped develop the concepts of least-cost energy services and conservation supply curves, the two most widely used tools for least-cost utility planning. In 1975, Rosenfeld began a campaign to simulate building energy use more accurately; this effort evolved into the DOE-2 whole-building simulation program, now the international standard for simulating building energy use.

Rosenfeld's other contributions include helping to establish the California Collaborative, a partnership among the state's utilities, the California Public Utilities Commission, and other interested groups to expand the state's energy-efficiency efforts. The Advanced Customer Technology Test program (ACT2) was the brainchild of Rosenfeld and the Rocky Mountain Institute's Amory Lovins to test advanced efficiency technology through demonstration projects funded by Pacific Gas & Electric, the United States' largest utility. Rosenfeld's current research interest is mitigating urban heat islands through light surfaces and shade trees. Prior to working in the energy-efficiency field, Rosenfeld had a distinguished career in nuclear and particle physics. He has authored more than 320 papers.

The Carnot award was named for a 19th-century French physicist whose work on energy conservation and the conversion of heat into work became the basis of the first and second laws of thermodynamics.

Dariush Arasteh has been recognized by the National Fenestration Ratings Council for "exemplary contributions to the NFRC mission through outstanding scientific and technical leadership achievement and leadership in the development of NFRC technical procedures." Arasteh is a scientist in the Windows and Daylighting Group.

Indoor Environment Program head Joan Daisey has been appointed Chair of the Science Advisory Board's Indoor Air Quality/Total Human Exposure Committee for 1994 by Carol Browner, Administrator of the U.S. Environmental Protection Agency.

A paper by Jon Koomey of the Center's Energy Analysis Program and Deborah Schechter and Deborah Gordon of the Union of Concerned Scientists received the Fred Burggraf Award of the National Research Council's Transportation Research Board. The paper is titled "Cost Effectiveness of Fuel Economy Improvements in 1992 Honda Civic Hatchbacks." The prize recognizes excellence in transportation research by scientists 35 or younger.

Max Sherman of the Indoor Environment Program received the Award for Best Paper by the International Energy Agency's Air Infiltration and Ventilation Center at its 14th annual conference in Copenhagen. The paper is titled "Ventilation: Energy Liabilities in U.S. Dwellings."

The Federal Laboratory Consortium has awarded Michael Siminovitch and Chin Zhang of the Lighting Systems Research Group (part of the Center's Building Technologies Program) the FLC Award for Excellence in Technology Transfer. They were recognized for developing energy-saving convective venting systems for compact fluorescent downlight fixtures. The technology helps cool the fixtures, increasing light outputs in lamps by as much as 20 percent (CBS News Winter 1994, p. 4). A second LBL team received a Certificate of Merit from the Federal Laboratory Consortium. Robert Sullivan and Michael Wilde of the Building Technologies Program were cited for developing prototype interactive multimedia applications ranging from building design and performance analysis tools to information databases on energy efficiency. The award commends outstanding work in transferring technology developed at federal laboratories to private-sector users.

Siminovitch also received the 1993 Award of Merit from the IEEE-Industry Application Society's Manufacturers System Development and Applications Department. He was cited for technical contributions to the development and market transfer of efficient compact fluorescent lamp fixtures.

Ruth Steiner of the Energy Analysis Program's International Energy Group is one of 15 recipients of the Switzer Foundation Environmental Fellowship for the 1993-94 academic year. Switzer fellowships are awarded to California graduate students whose research is directed toward reducing and preventing air, water, or soil pollution.

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CIEE Conference at Berkeley

Berkeley has been chosen as the site of the California Institute for Energy Efficiency's fourth annual conference, to be held in late July. The three-day event is designed to communicate the latest developments in energy-efficiency research to CIEE's sponsoring organizations, utility representatives, and researchers. Although CIEE's overall goal is to increase California's energy efficiency, past conferences have also attracted non-Californians interested in CIEE as a model of how a national lab, universities, and industry can work together.

Established in 1988 by the University of California in collaboration with LBL, CIEE develops technologies that will increase the efficiency of California's energy services, thereby sustaining the environment and the economy. Today, the CIEE partnership comprises California's electric and gas utilities, the California Energy Commission, the California Public Utilities Commission, and the U.S. Department of Energy, in addition to UC and LBL. These organizations provide financial support and guidance to help CIEE fund and manage a multiyear research program and several one-year exploratory projects focusing on buildings, industry, and transportation.

Denise Thiry
(510) 486-4221; (510) 486-5929 fax

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Center Scientists Assist Mexico

The U.S. Agency for International Development (USAID) has approved funds for LBL to provide technical assistance to Mexico's Comisi—n Nacional de Ahorro de Energ'a (CONAE) in developing energy standards for commercial buildings. Past experience has shown that building standards can be a highly cost-effective energy conservation measure, especially for growing economies such as Mexico's.

With very few energy-engineering programs in the country, and no building energy standards at the present moment, Mexico is taking advantage of LBL's assistance to help ensure that the expertise to develop standards is available. Recent national legislation ("Ley Federal Sobre Metrologia y Normalizaci—n") abolished Mexico's previous mandatory national standards by October 1994 and established a framework for writing mandatory and optional standards in different regulatory fields. The legislation requires Mexico's Ministries to develop new standards in the mandatory categories, which include environmental and consumer protection.

Given the job of developing energy-related standards, CONAE has begun looking at nonresidential buildings. Last August, two CONAE professionals visited LBL facilities, the California Energy Commission, and the National Resources Defense Council to discuss the building-standards process in the U.S. Their visit was followed by an intensive week-long workshop in Mexico during which representatives of LBL, Pacific Northwest Laboratory, the California Energy Commission, and ASHRAE's technical committee on standard 90.1 worked with CONAE staffers to develop a draft standard. This draft will probably become the basis for the final standard. Center researchers are already at work providing follow-up technical assistance, which began with a cost-benefit analysis of the proposed standard and will continue with training, documentation assistance, and customer surveys.

—Nathan Martin

Nathan Martin
Energy Analysis Program
(510) 486-5137; (510) 486-6996 fax

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World Wide Web Information Servers

Lawrence Berkeley Laboratory recently announced a gopher and World Wide Web site. To get to the web site, telnet to www.lbl.gov, login: www. Access is provided to LBL's gopher, library catalog, and publication list.

The Center is funding the implementation of a WWW network node for on-line access to publications, databases, and documents full of hypermedia links to other documents or information systems from the Energy & Environment Division. Full implementation is expected by May 1994, and will include access to a variety of information from all the research programs and centers.

The technology transfer project calls for this newsletter to be published on WWW using the Mosaic interface under development at the National Center for Supercomputer Applications. Mosaic is a high-end browser supported on all Macs, PCs running Windows, and Unix-based systems running X Windows.

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New Center for Building Science Patents

#5,270,092	12/14/93	Gas-Filled Panel Insulation	(Brent T. Griffith, Dariush K. Arasteh, Stephen E. Selkowitz)
#5,277,653	1/11/94	Gas Flow Means for Improving Efficiency of Exhaust Hoods	(Ashok J. Gadgil)

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Sponsors of research described in this issue include:

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- U.S. Department of Energy
- Office of Building Technologies
- Office of Health and Environmental Research
- Office of Utility Technologies
- U.S. Environmental Protection Agency